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SILVICAL CHARACTERISTICS of

BUR OAK

SCHOOL OF FORESTRY
UNIVERSITY OF MINN SOTA
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This is the thirteenth of a series of 17 papers dealing with the silvical characteristics of forest trees important in the Central States region. The following species are included in this series. (Those marked with an asterisk have already been published.)

*Ohio buckeye
Yellow buckeye
*Northern red oak
*Black oak
*Chinkapin oak
*Pin oak
*White oak
*Swamp white oak
*Bur oak
Butternut
*Black walnut
*Shellbark hickory
*Sycamore
*Honeylocust
Hackberry
Black locust
*Eastern redcedar

Papers covering additional important American species will be issued by other Forest Experiment Stations of the U. S. Forest Service.

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W. G. McGinnies, Director

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Silvical Characteristics of Bur Oak

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Bur oak (Quercus macrocarpa Michx.) has the distinction of possessing the largest leaves and acorns of all of the oaks. It is also called mossycup oak and mossy-overcup oak because of the conspicuous fringe of matted hairs on the acorn. Other local names are blue oak and scrub oak (33) 1/.

The bur oak grows to be one of the largest trees in the Central States region but dwindles in size to a small shrub as it ranges northwestward, extending farther in this direction than other eastern oaks. Its commercial uses are similar to those for white oak and it is frequently classed with that species in the market.

1/ Numbers in parentheses refer to Literature Cited, p. 1[illegible]

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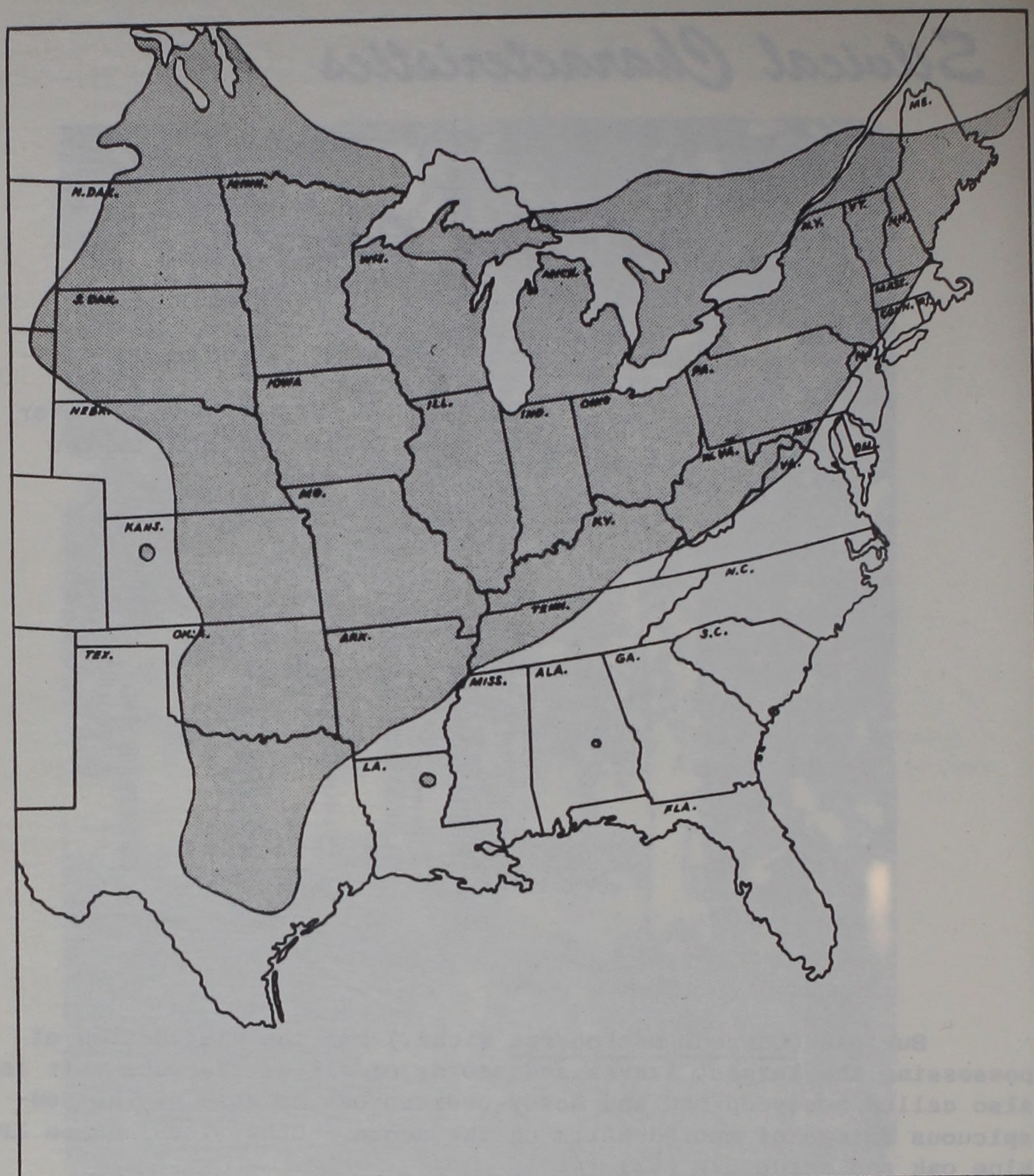

SITE

Climate

This species is one of the most drought-resistant of the oaks, with average annual precipitation as low as 15 inches in the northwest limits of its range. Here, the average minimum temperature goes down to -40° F., and the average growing season lasts only 100 days (28).

To the south, bur oak grows in areas having average precipitation exceeding 50 inches per year, minimum temperatures of 20° F. and, a growing season of 260 days. Near-optimum conditions for its development occur in southern Illinois and Indiana where the averages for annual precipitation is about 45 inches, minimum temperature is -20° F., and length of growing season is 190 days.

Soils

Bur oak grows best on rich, moist, well-drained soil, but it also has exceptional ability to establish itself on dry, exposed sandy plains and on loamy slopes of south and west exposures in the subclimax prairies of the Midwest (1, 47). It often dominates on other severe sites such as thin soils of limestone or sandstone, heavy claypan soils with fair surface drainage, gravelly ridges, and coarse-textured loessal hills as in western Iowa (fig. 2) (34). Elsewhere, it is found on heavy loams, usually well-drained to fairly dry black prairie loam (47).

The occurrence of bur oak in upland locations appears to be closely linked with, but not limited to, calcareous sites. In the driftless area of southwestern Wisconsin, clumps of bur oak are found on limestone ridges (60), and in Kentucky, this species is normally found on limestone soils rather than on soils derived from shales and sandstone (35).

Physiography

On bottomlands of the Central States region and southward, bur oak grows usually as scattered individuals on moist flats and on hummocky or washboardy topography in both first and second bottoms (41). It occurs in stream bottoms and on terraces in the western part of its range, and is found along adjacent draws and upper slopes where it becomes the first tree species to establish itself

on the edges of the prairie (27, 34, 47, 49). Bluffs along the Missouri River and its tributaries in eastern Nebraska are frequently covered with bur oaks which range in size from small trees near the base of the bluffs to dense thickets of low straggling bushes near the tops (1, 3, 27).

From the Ohio River northward, it occupies a variety of sites, including "wet openings" in the oak-hickory forest type (39). It dominates only on exposed ridges and dry slopes where it often occurs in pure stands. Bur oak frequently forms a fringe between the prairie and edges of upland timber belts in northern Illinois and eastern Iowa, notably at the outer edge of "breaks" and bluffs along streams and around limestone outcrops. In this same territory, it occurs as a good timber tree in the bottoms but is mostly absent in the intervening areas.

Associated Species

Because of its tolerance to a wide range of soil and moisture conditions, bur oak is found in company with a great many other tree species (23, 36, 37, 46). In the upper bottomlands of the south and central parts of its range, representative species associated with bur oak are American and slippery elms, shellbark hickory, white ash, hackberry, swamp white oak, basswood, red maple, and eastern cottonwood. Associates in oak-hickory forest types include eastern white pine, northern red, white, and black oaks, shagbark and bitternut hickories, and American elm. Bur oak is found in the Aspen type of the Northern Great Plains, the Maple-Basswood type of Minnesota, and the Black ash-American elm-Red maple type in New York.

Bur oak becomes especially prominent on many of the drier sites in the northwestern part of its range, occurring in mixed stands with American elm, green ash, bitternut hickory, and white oak, and often forming nearly pure stands. In North Dakota, for example, the Bur oak type occupies about 19 percent of the forest land (56).

Shrubs are especially abundant in the bur oak forests of the plains region (1, 5, 58). Predominant among them are American hazelnut (Corylus americana), coralberry (Symphoricarpos orbiculatus), roughleaf cornel (Cornus asperifolia), and smooth sumac (Rhus glabra). Hawthorn (Crataegus spp.), western snowberry (Symphoricarpos occidentalis), and prairie crabapple (Malus ioensis) are common associates on the prairie borders (3).

The acorns of bur oak make up much of the food of red squirrels. Observations have also shown them to be eaten by wood ducks, white-tailed deer, varying hare, pine mouse, and the thirteen-striped squirrel (53, 54).

LIFE HISTORY

Seeding Habits

Full flowering of bur oak occurs shortly after the leaves appear, varying from about the first of April in the southern part of its range to about mid-June in the north (32). Pollen from one tree appears to germinate better on the stigmas of another, thus favoring cross-pollination (42).

The acorns become ripe within 1 year, dropping from the tree as early as August or as late as November. Germination usually takes place soon after seedfall, but in the northern part of the bur oak range there appears to be a climatic form (var. olivaeformis) whose acorns remain dormant over winter and then germinate in the following spring (52).

Commercial seed crops may be borne by bur oak trees up to 400 years old--a greater age than that reported for any other American oak species (52). The minimum commercial seed-bearing age is 35 years and the optimum is 75 to 150 years. Good seed crops occur every 2 to 3 years with light crops in intervening years. Each tree probably yields between 1/4 and 1 1/2 bushels, similar to that for other species in the white oak group. Commercial seed averages about 85 percent sound, and the germinative capacity is given as 45 percent, but should run much higher under natural conditions.

The acorns are disseminated mainly by gravity and squirrels, and to a limited extent by water.

Vegetative Reproduction

Vigorous sprout growth follows the burning or cutting of bur oak trees of pole size or smaller. But except for seedling sprouts, the quality and form of the succeeding stems are relatively poor. Some sprout growth is produced by larger trees also, but the effect of size or age of parent tree has not been definitely established.

Seedling Development

Before germination, oak acorns are often subject to serious depredations by animals, especially of the rodent family (29, 30, 57). A moderate cover of leaf litter is thought to help germination by concealing the acorns as well as protecting them from excessive drying. However in Iowa uplands, germination and early seedling development from planted bur oak, white oak, and northern red oak acorns were recently found to be best on areas where litter had been removed[2/]. Here, litter-covered acorns seemed to be more susceptible to pilferage by rodents and the newly developing seedlings to fungus and insect attack.

Reproduction of bur oak is often prolific in open bottomland areas, but here it is frequently killed by high water during the growing season (40). A Nebraska study (2) conducted under field conditions showed that about 30 percent of the acorns germinate within 1 month after seedfall, and the new seedlings are less susceptible to freezing than are those of white oak. Throughout its development, bur oak appears to require a high percentage of full sunlight.

Root growth is very rapid and the taproot penetrates deeply before the leaves unfold. At the end of the first growing season, roots have been found at depths of 4 1/2 feet with a total lateral spread of 30 inches (25). This strong early root development explains why bur oak can be a pioneer species on dry, exposed sites and can successfully establish itself in competition with prairie shrubs and grasses.

The survival of planted bur oak seedlings ranks high in comparison with other hardwoods. Its growth rate in New York plantations did not appear to be affected by site conditions there (55), but in Iowa growth was markedly poorer on previously cultivated fields than on uncultivated lands (22).

Sapling Stage to Maturity

Growth Rates and Size Attained

Bur oak is a relatively slow-growing tree. In 12- to 16-year-old plantations on Iowa upland sites, average annual height growth of bur oak ranged from 0.28 feet to 1.67 feet and diameter growth from less than 0.1 inch to more than 0.25 inch (22). In New York plantations (55), height growth averaged 1/2 foot per year, and in the shelterbelts of the northern Great Plains an annual growth of about 1 foot was reported for trees kept under clean cultivation (19).

2/ Krajicek, John E. Some factors affecting oak acorn germination. Cent. States Forest Expt. Sta. unpublished manuscript. 1957.

Taproot development is rapid and deep with very abundant laterals and sinkers. The taproot of 8-year-old saplings in upland clay soils of Missouri went down more than 14 feet and primary laterals extended to distances up to 11 feet (7). In prairie areas, roots of bur oak and hackberry have been found at depths of 10 to 20 feet (24), and a 43-year-old bur oak tree had lateral spread of 41 feet although the tree was only 20 feet tall (62). Another study of a tree with a 14-inch basal diameter revealed that the weight of the roots equaled that of the tops, and root volume was only about 10 percent less than top volume (59).

Forest survey statistics for Iowa[3/] reveal that 10-year diameter growth of bur oak in the bur oak type averaged about 1/2 inch for pole-sized trees and about 1 inch for trees of sawtimber size. More rapid growth has been reported in Kansas (27) where trees 35 to 40 years old averaged 1 inch of diameter growth in 3.8 years. Approximately the same rate has been observed in the northern Mississippi Delta Region (40).

Bur oak is said to have reached a height of 170 feet and diameter of 7 feet in the lower Ohio Valley (23). Growing as scattered individuals on the better sites, mature trees generally average 80 to 100 feet tall, 3 to 4 feet in diameter, and 200 to 300 years of age. Characteristically, they have a massive, clear trunk and a broad, open crown of stout branches.

In the oak openings of southern Wisconsin and in the prairie border areas to the south and west, bur oak often forms nearly pure stands. The trees are widely spaced, short-boled, and rather uniform in size. A 50- to 65-year-old stand in eastern Nebraska was 30 to 40 feet tall and stems were spaced at intervals of 10 to 40 feet (59). Heights of as much as 70 feet may be reached on the more fertile soils in this region, but on sites such as dry, limestone ridges, the trees may be less than 25 feet tall at 150 years of age (60). Observations in Minnesota (17) indicate that bur oak is shorter-lived on the poorer sites.

Iowa timber volumes in the bur oak type have been estimated at about 1100 board-feet per acre, three-fourths of which is bur oak itself (11). Net board-foot growth rate of the species in this State averaged 4 percent (including net ingrowth and deducting for mortality).

3/ Morgan, James T. Iowa forest survey data. Lake States Forest Expt. Sta. unpublished data. 1957.

Reaction to Competition

Along with other oaks, bur oak is rated intermediate in tolerance (6). One writer (20) judges it somewhat more tolerant than northern red and white oak, but on the prairie margins bur oak stands are often invaded by black oak, white oak, and bitternut hickory (4, 14, 48). Bur oak reproduction under old white pine-bur oak stands in Minnesota reaches only sapling size before dying from suppression, and these stands are being replaced by maple-basswood communities (9).

In bottomland stands, the usual distribution of bur oak as scattered, older trees further indicates that it cannot reproduce successfully in competition with faster growing or more tolerant associates.

Climax Position of Species

In the bottomlands of northern Ohio, bur oak appears as a secondary species in the elm-black ash-soft maple association, together with shellbark hickory, green and white ash, and following such species as pin oak and swamp white oak (45). Where drainage is better, other secondary species include basswood, black cherry, shagbark hickory, and black walnut.

On the prairie edges, bur oak is a pioneer tree species, commonly succeeded by northern pin oak, black oak, white oak, and bitternut hickory, in the succession toward sugar maple and basswood or sugar maple and beech (14, 15, 47). It may possibly be climax with hickory on extremely dry south aspects and on thin, stony soils.

ENEMIES AND HAZARDS

Insects

Bur oak is seldom subject to serious injury by insects, althoug June beetles (*Phyllophaga* spp.) are occasionally destructive (51). The adult beetles can cause much defoliation, and the larvae cause damage in nurseries by feeding on roots. Other insects of local importance are the variable oak leaf caterpillar (*Heterocampa mantes*), a defoliator, and bur oak kermes (*Kermes pubescens*) whose attacks may distort the leaves and kill many twigs (26). In the southern portion of its range, the tree is considered to be of generally higher quality than overcup oak because of its freedom from insects (40).

Diseases

Oak wilt (Ceratocystis fagacearum) infection is much less serious on bur oak than on members of the red oak group (8, 31, 43). Root-grafting and spread of the disease from infected bur or white oak to adjacent oaks is infrequent (38). In approximately half of the infected trees, the fungus is "buried" by new wood and the trees apparently recover. In the other half, the trees usually die slowly over a period of 2 or 3 years, and fungus mats are rarely formed (31, 38).

The species is susceptible to the cotton root rot fungus (Phymatotrichum omnivorum) and Strumella canker (S. coryneoidea). Half of the trees in a 20-year-old plantation in Pennsylvania became infected with the latter disease, and of these, nearly a fourth had died (18). Other fungi that have been isolated from diseased portions of bur oak included Dothiorella canker and dieback (D. quercina), Phoma canker (P. aposphaerioides), Conothyrium dieback (C. truncisedum), and Armillaria root rot (A. mellea) (10).

Fire

The larger bur oak trees are fairly resistant to injury by fire and this, together with resistance to drought and disease, probably account for maintenance of the bur oak "openings" which were the principal forests over much of southern Wisconsin at the time of homesteading (13, 48). The presence of very large bur oaks in the sugar maple-basswood community of the Big Woods of Minnesota has been attributed to its thick fire-resisting bark which enabled it to survive repeated burning and freed it from competition by less fire-resistant species (15).

Weather

Bur oak is capable of withstanding a wide range of moisture and site conditions. In the northwest part of its range, it is considered one of the most xeric trees of the area (5, 17, 60). During severe drought conditions in Iowa, unpastured bur oak stands on dry, exposed slopes were not injured, but in pastured woods, drought injury occurred even on protected sites (34). This difference was attributed to reduced aeration (caused by trampling) that had limited the depth of root penetration, the rate of absorbing root production, and the efficiency of the roots present.

At the other extreme of soil moisture conditions, bur oak has been found somewhat resistant to flooding injury. In company with species such as swamp white oak and pin oak, bur oak survived constant flooding by impounded water for periods up to 3 years (21, 63).

Miscellaneous

Bur oak in New York plantations was rarely attacked by mice, unlike many of the other hardwood species (55). Also, planted bur oak tolerates city-smoke conditions better than most other species of oak (53).

RACES AND HYBRIDS

As previously noted, there appears to be a northern form of bur oak that has been called Q. macrocarpa var. olivaeformis. Acorns of this form germinate in the spring following seedfall rather than soon after falling, and in nursery practice they are benefited by stratification (52). Their size is about half that of the southern form, and the acorn cup is much thinner and smaller (16, 44, 46). Cleaned seed averages 270 per pound compared to only 75 per pound for the typical species (52).

Five hybrids of bur oak have been recognized (33). These are crosses with white oak, with swamp chestnut oak (Q. michauxii), with chinkapin oak (Q. muehlenbergii), with post oak (Q. stellata), and with swamp white oak.

SPECIAL FEATURES

Leaves of bur oak are the largest of all the oaks--6 to 12 inches long and 3 to 6 inches broad at the upper half. The development of corky ridges on younger branches is typical, often reaching widths of an inch or more (12).

Acorns vary greatly in size and shape. In the southern range of the species, the fruit is often 2 inches in length, living up to the specific name "macrocarpa" meaning large-fruited. It is downy at the apex, and enclosed from half to all of its length in a deep, bowl-shaped cup that has a moss-like fringe of hairs at its rim (41). Some of the acorns are bitter; others have a sweet and pleasant, nut-like flavor and formerly were used on occasion by Indians for food (61).

TREE SPECIES MENTIONED

Green ash	-	*Fraxinus pennsylvanica* Marsh.
White ash	-	*F. americana* L.
American basswood	-	*Tilia americana* L.
American beech	-	*Fagus grandifolia* Ehrb.
Black cherry	-	*Prunus serotina* Ehrb.
Eastern cottonwood	-	*Populus deltoides* Bartr.
American elm	-	*Ulmus americana* L.
Slippery elm	-	*U. rubra* Muehl.
Hackberry	-	*Celtis occidentalis* L.
Bitternut hickory	-	*Carya cordiformis* (Wangenh.) K. Koch
Shagbark hickory	-	*C. ovata* (Mill.) K. Koch
Shellbark hickory	-	*C. laciniosa* (Michx. f.) Loud.
Red maple	-	*Acer rubrum* L.
Sugar maple	-	*A. Saccharum* Marsh.
Black oak	-	*Quercus velutina* Lam.
Chinkapin oak	-	*Q. muehlenbergii* Engelm.
Northern pin oak	-	*Q. ellipsoidalis* E. J. Hill
Northern red oak	-	*Q. rubra* L.
Overcup oak	-	*Q. lyrata* Walt.
Pin oak	-	*Q. palustris* Muenchh.
Post oak	-	*Q. stellata* Wangenh.
Swamp chestnut oak	-	*Q. michauxii* Nutt.
Swamp white oak	-	*Q. bicolor* Willd.
White oak	-	*Q. alba* L.
Eastern white pine	-	*Pinus strobus* L.
Black walnut	-	*Juglans nigra* L.

LITERATURE CITED

(1) Aikman, J. M.
1927. Distribution and structure of the deciduous forest in eastern Nebraska. Univ. Nebr. Studies 26: 1-75, illus.

(2) -------
1934. The effect of low temperature on the germination and survival of native oaks. Iowa Acad. Sci. Proc. 41: 89-93, illus.

(3) -------
1935. Possibilities of shelterbelt planting in the plains region. Section 13. Native vegetation of the region. U. S. Forest Serv., Lake States Forest Expt. Sta. Spec. Bul., pp. 155-174, illus.

(4) ------- and Smelzer, A. W.
1938. The structure and environment of forest communities in central Iowa. Ecol. 19: 141-170, illus.

(5) Albertson, F. W., and Weaver, J. E.
1945. Injury and death or recovery of trees in prairie climate. Ecol. Monog. 15: 393-433, illus.

(6) Baker, F. S.
1949. A revised tolerance table. Jour. Forestry 47: 179-181.

(7) Biswell, H. H.
1935. Effect of environment upon the root habits of certain deciduous forest trees. Bot. Gaz. 96: 676-708, illus.

(8) Bretz, T. W.
1951. Oak wilt. Jour. Forestry 49: 169-171.

(9) Buell, Murray F., and Cantlon, John E.
1951. A study of two forest stands in Minnesota with an interpretation of the prairie-forest margin. Ecol. 32: 294-316, illus.

(10) Carter, J. C.
1941. Preliminary investigation of oak diseases in Illinois. Ill. Nat. Hist. Survey Bul. 21: 195-230, illus.

(11) Central States Forest Experiment Station
1956. Iowa forest statistics. Cent. States Forest Expt. Sta. Forest Survey Release 20, 58 pp., illus.

(12) Collingwood, G. H., and Brush, Warren D.
1947. Knowing your trees. 312 pp., illus. Washington.

(13) Cottam, Grant
1949. The phytosociology of an oak woods in southwestern Wisconsin. Ecol. 30: 271-287, illus.

(14) Curtis, J. T., and McIntosh, R. P.
1951. An upland forest continuum in the prairie-forest border region of Wisconsin. Ecol. 32: 476-496, illus.

(15) Daubenmire, Rexford F.
1936. The big woods of Minnesota: its structure and relation to climate, fire, and soils. Ecol. Monog. 6: 231-268, illus.

(16) Deam, Charles C., and Shaw, T. E.
1953. Trees of Indiana. Ind. Dept. Conserv. Pub. 13, 330 pp., illus.

(17) Deters, M. E.
1943. Silvicultural aspects of woodland management in southeastern Minnesota. Minn. Agr. Expt. Sta. Tech. Bul. 157, 71 pp., illus.

(18) Fergus, Charles L.
1951. Strumella canker on bur oak in Pennsylvania. Phytopath. 41: 101-103.

(19) George, Ernest J.
1953. Tree and shrub species for the northern great plains. U. S. Dept. Agr. Cir. 912, 46 pp., illus.

(20) Green, George R.
1934. Trees of North America, 344 pp., illus. Ann Arbor.

(21) Green, William E.
1947. Effect of water impoundment on tree mortality and growth. Jour. Forestry 45: 118-120.

(22) Hansen, Norman J., and McComb, A. L.
1955. Growth, form and survival of plantation-grown broadleaf and coniferous trees in southeastern Iowa. Iowa Acad. Sci. Proc. 62: 109-124, illus.

(23) Harlow, William M., and Harrar, Elwood S.
1951. Textbook of dendrology. Ed. 2, 542 pp., illus. New York.

(24) Hayes, F. A., and Stoeckler, J. H.
1935. Possibilities of shelterbelt planting in the plains region. Section 12. Soil and forest relationships of the shelterbelt zone. U. S. Forest Serv., Lake States Forest Expt. Sta. Spec. Bul., pp. 111-115.

(25) Holch, A. E.
1931. Development of roots and shoots of certain deciduous tree seedlings in different forest sites. Ecol. 12: 259-298, illus.

(26) Houser, J. S.
1918. Destructive insects affecting Ohio shade and forest trees. Ohio Agr. Expt. Sta. Bul. 332, pp. 161-487, illus.

(27) Kellogg, R. S.
1905. Forest belts of western Kansas and Nebraska. U. S. Forest Serv. Bul. 66, 4 pp., illus.

(28) Kincer, J. B.
1941. Climate and weather data for the United States. U. S. Dept. Agr. Yearbook 1941: 685-747.

(29) Korstian, Clarence F.
1927. Factors controlling germination and early survival in oaks. Yale Univ., School of Forestry Bul. 19, 115 pp., illus.

(30) Krajicek, John E.
1955. Rodents influence red oak regeneration. Cent. States Forest Expt. Sta. Note 91, 2 pp.

(31) Kuntz, J. E., and Riker, A. J.
1956. Oak wilt. Univ. Wis. Agr. Expt. Sta. Bul. 519, 12 pp., illus.

(32) Lamb, G. N.
1915. A calendar of the leafing, flowering, and seeding of the common trees of the eastern United States. U. S. Monthly Weather Rev., Sup. 2, pp. 3-19, illus.

(33) Little, Elbert L.
1953. Check list of trees of the United States, including Alaska. U. S. Forest Serv. Agr. Handb. 41, 472 pp.

(34) McComb, A. L., and Loomis, W. E.
1944. Subclimax prairie. Bul. Torrey Bot. Club 71: 46-76, illus.

(35) McHargue, J. S., and Roy, W. R.
1932. Mineral and nitrogen content of the leaves of some forest trees at different times in the growing season. Bot. Gaz. 94: 381-393, illus.

(36) Miller, H. C. E., and Buell, M. F.
1956. Life-form spectra of contrasting slopes in Itasca Park, Minnesota. Bot. Gaz. 117: 259-263.

(37) Pammel, L. H.
1907. A comparative study of the vegetation of swamp, clay, and sandstone areas in western Wisconsin, southeastern Minn., northeastern, central, and southeastern Iowa. Davenport Acad. Sci. Proc. (1904-1906) 10: 32-126, illus.

(38) Parmenter, J. R., Kuntz, J. E., and Riker, A. J.
1956. Oak wilt development in bur oaks. Phytopath. 46: 423-436, illus.

(39) Potzger, John E., and Keller, C. O.
1952. The beech line in northwestern Indiana. Butler Univ. Bot. Studies 10: 108-113.

(40) Putnam, John A.
1951. Management of bottomland hardwoods. U. S. Forest Serv. South. Forest Expt. Sta. Occas. Paper 116 pp.

(41) ------- and Bull, H.
1932. The trees of the bottomlands of the Mississippi River Delta Region; their distribution, occurrence by site and cover type, utilization in the Delta, and the distinguishing characteristics of the principal and most common species and groups of species. U. S. Forest Serv. South. Forest Expt. Sta. Occas. Paper 27, 207 pp.

(42) Pyatnitsky, S. S.
1948. On pollination in oaks and the germination of pollen on the stigmas. (Abstract.) Forestry Abs. 9: 282.

(43) Riker, A. J.
1951. The spread of oak wilt in local areas. (Abstract.) Phytopath. 41: 30.

(44) Rosendahl, Carl Otto, and Butters, Frederic K.
1928. Trees and shrubs of Minnesota. Illus.

(45) Sampson, Homer C.
1930. Succession in the swamp forest formation in northern Ohio. Ohio Jour. Sci. 30: 341-357, illus.

(46) Sargent, Charles S.
1933. Manual of the trees of North America (exclusive of Mexico). Ed. 2, 910 pp., illus. Boston and New York.

(47) Society of American Foresters
1954. Forest cover types of North America (exclusive of Mexico). 67 pp. Washington

(48) Stout, A. B.
1944. The bur oak openings of southern Wisconsin. Wis. Acad. Sci. Trans. 36: 141-161, illus.

(49) Turner, L. M.
1937. Some soil characteristics influencing the distribution of forest types and rate of growth of trees in Arkansas. Jour. Forestry 35: 5-11.

(50) U. S. Department of Agriculture
1941. Climate and man. U. S. Dept. Agr. Yearbook 1941, 1248 pp., illus.

(51) -------
1949. Trees. U. S. Dept. Agr. Yearbook 1949, 944 pp., illus.

(52) U. S. Forest Service
1948. Woody-plant seed manual. U. S. Dept. Agr. Misc. Pub. 654, pp. 297-304, illus.

(53) Van Dersal, William R.
1938. Native woody plants of the United States, their erosion control and wildlife values. U. S. Dept. Agr. Misc. Pub. 303, 362 pp.

(54) Van Dersal, William R.
1940. Utilization of oaks by birds and mammals. Jour. Wildlife Mangt. 4: 404-428, illus.

(55) Wallihan, E. F.
Plantations of northern hardwoods. Some factors influencing their success. New York Agr. Expt. Sta. Bul. 853, 31 pp., illus.

(56) Warner, John R., and Chase, Clarence D.
1956. The timber resource of North Dakota. U. S. Forest Serv. Lake States Forest Expt. Sta. Paper 36.

(57) Watt, A. S.
1919. On the causes of failure of natural regeneration in British oakwoods. Jour. Ecol. 7: 173-203, illus.

(58) Weaver, J. E., Hanson, Herbert C., and Aikman, John M.
1925. Transect method of studying woodland vegetation along streams. Bot. Gaz. 80: 168-187, illus.

(59) ------- and Kramer, J.
1932. Root systems of Quercus macrocarpa in relation to the invasion of prairie. Bot. Gaz. 94: 51-85, illus.

(60) Wilde, S. A., Whitford, Phillip E., and Youngberg, C. T.
1948. Relation of soils and forest growth in the drift-less area of southwestern Wisconsin. Ecol. 29: 173-180, illus.

(61) Will, G. F.
1949. The burr oak. N. and S. Dak. Hort. 22: 58.

(62) Yeager, A. F.
1935. Root system of certain trees and shrubs grown on prairie soils. Jour. Agr. Res. 51: 1085-1092, illus.

(63) Yeager, Lee E.
1949. Effect of permanent flooding on a river-bottom timber area. Ill. Nat. Hist. Surv. Bul. 25: 29-65, illus.

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